HARVESTING WITH COMBINES

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CONTENTS

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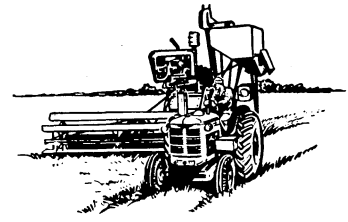
HARVESTING WITH COMBINES



By R. B. GRAY, *supervising agricultural engineer, Agricultural Engineering Research Branch, Agricultural Research Service*[1]

To avoid breakdowns and delays and to make adjustments for the best threshing and cleaning job, the farmer-operator should be thoroughly familiar with his combine and its capabilities. This bulletin presents information that will help such an operator use his combine effectively in a variety of crops and under a variety of conditions.

SIZES AND TYPES OF COMBINES

Combines are of two general types—the pulled type and the self-propelled type. The former may be obtained in sizes ranging from 5 to 20 feet, the latter from 7 to 20 feet (fig. 1). Machines with a 10-foot cut or larger are generally available in either hillside or level-land models.

Hillside machines are equipped with brakes and a device for leveling the thresher to prevent the threshed grain from accumulating on one side of the sieves (fig. 2). They are used primarily in hilly areas like the Palouse country of the Northwest.

Certain models of hillside combines manufactured by one company are built with a counterbalance pendulum unit which automatically levels the grain-cleaning shoe whenever the combine moves up or down a slope. This feature is designed to keep the shoe level so the chaff and grain always move uniformly over the sieves. As the combine dips forward on a downhill grade, the pendulum swings forward, lowering the shoe to the correct level. On the uplift, the pendulum swings backward, raising the shoe to the proper height.

Level-land combines are designed for use in areas where grades are not steep enough to interfere with the performance of the machine.

Hillside combines and many of the larger level-land models have hinged headers equipped with a grain wheel (fig. 2) on the outer end for flexibility on uneven ground. On others both the thresher and header are attached to the same frame, which is carried on wide-tread or rubber-tired wheels. Grain-handling facilities also vary. Some machines may be obtained with a choice of grain-bin, wagon-hitch, or grain-bagging attachment.

The self-propelled combine can go directly into the field without previous opening and can bypass green patches, woods, or unripened grain that is to be cut later. This machine differs from the pulled type in that the cutter bar projects out in front instead of behind the tractor and the grain as it is cut is conveyed from both ends of the platform to the center, rather than to one end, from which it is elevated into the threshing cylinder. For use in rice a few special attachments

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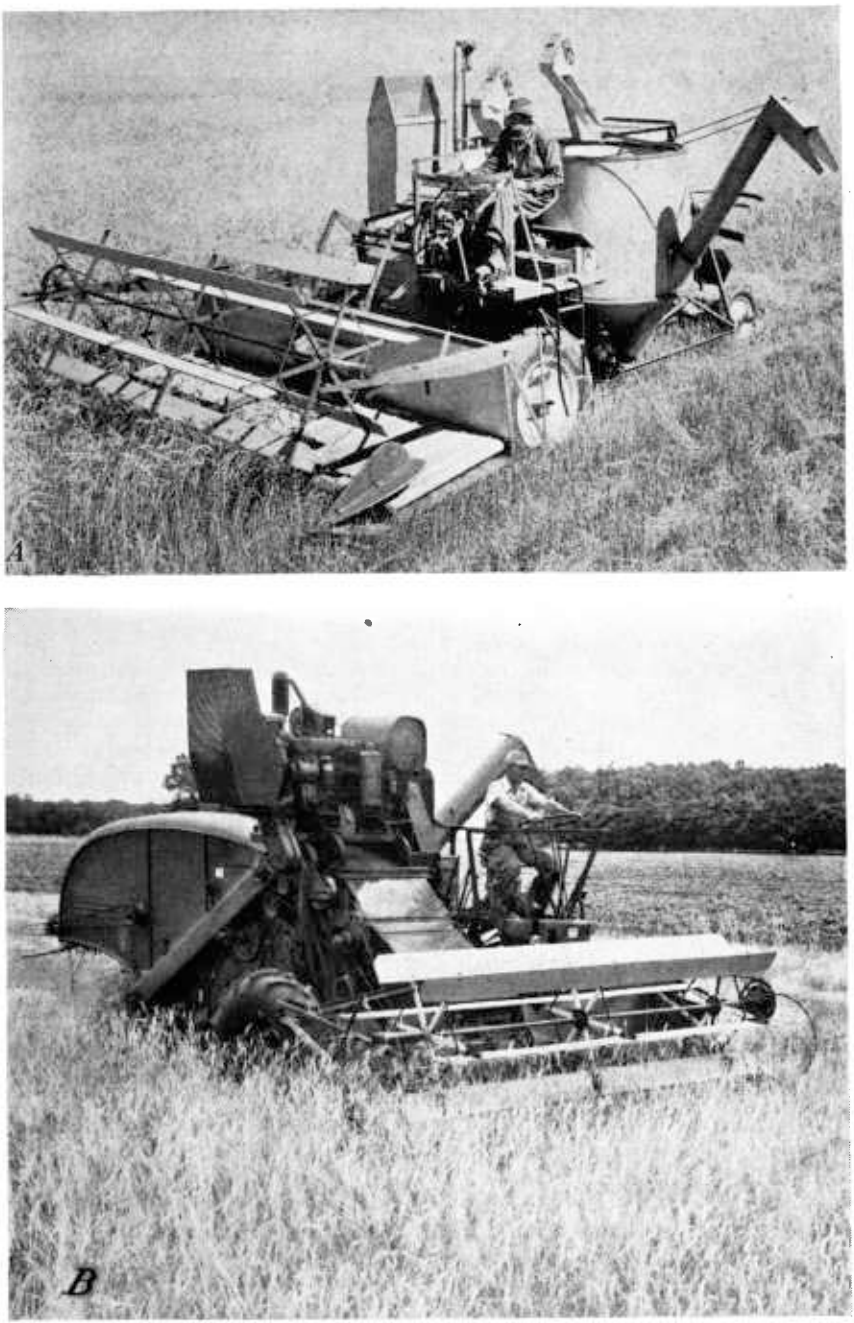

FIGURE 1.—Self-propelled combines: *A*, Platform provided with canvas conveyor feed; *B*, platform provided with auger feed.

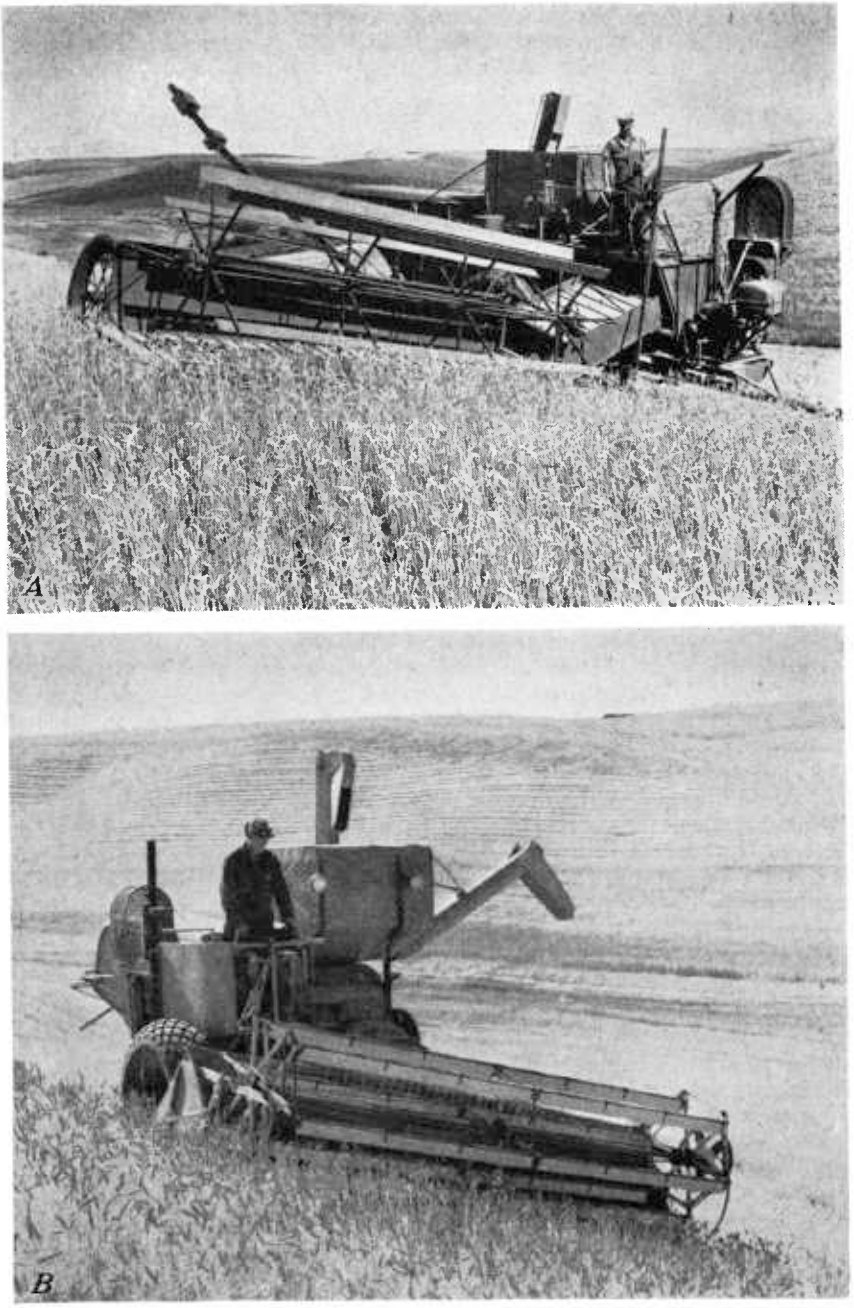

FIGURE 2.—Hillside combines equipped with grain tanks: *A*, Pulled type; *B*, self-propelled type.

and deep-lugged tires on the drive wheels are necessary. Under exceptionally bad field conditions it is sometimes desirable to mount the combines on crawler tracks rather than on wheels. Pickup attachments are available for the self-propelled machine as well as for the pulled type.

Most manufacturers make use of the rasp-bar or angle-bar cylinder although some makes and models are fitted with the spike-tooth type. In the different makes and models of combines wide variations also exist in the location and arrangement of parts. To show all such variations is beyond the scope of this bulletin; the illustrating of certain types should not be construed as implying any endorsement by the United States Department of Agriculture.

DESCRIPTION AND FUNCTION OF PARTS

The four major units of a combine are the header, the thresher, the separator, and the cleaning device. All combines have these four essential parts.

Header and Platform

The header, which cuts the grain and conveys it to the thresher, is composed of a reel, sickle, conveyor, and other parts making up the platform assembly. The sickle, reel, platform, and platform canvas are similar to those used on a binder or header. Some manufacturers, however, use spiral conveyors, or augers, instead of canvas for conveying the crop to the feeder house on the combine.

Small machines (5- to 6½-foot cut) may be operated by the power takeoff from a tractor, or with an engine mounted on the combine for operating all moving parts. These features are optional on practically all makes. The larger sizes are all equipped with an engine. In the past, power takeoff machines were not entirely satisfactory, because of lack of sufficient tractor engine power for moving the machine over the field and operating the moving parts. However, the use of rubber tires on tractors and also on combines reduces the power required for moving the machinery over the field, leaving a larger percentage of it available for operating the moving parts.

Forward speeds up to 4 and 5 miles per hour can be made under favorable conditions, particularly with the 5- and 6-foot sizes. Machines mounted on rubber tires have double the speed of those mounted on steel wheels. A separate clutch for the power takeoff or "live" power takeoff, if available, makes this type of equipment more practicable in that it enables the operator to stop the forward motion of the tractor and combine without interfering with the speed of the cylinder and other moving parts.

The reel should be set so that the slats will strike the grain just below the heads and slightly ahead of the sickle to minimize shattering. The exact position of the reel depends on the height of the grain, the condition of the straw, and the quantity of straw cut with the grain. The reel can generally be set so that the slats will push the cut grain well back on the platform.

The correct speed of the reel is usually governed by the speed of ground travel. The reel should travel a little faster than ground travel so that it supports the grain as it is cut off at the cutter bar and laid back onto the platform. Variable-speed reels are available on

some makes of self-propelled combines. Ground-driven reels are available on other makes for synchronizing the reel speed with ground travel of the main drive wheels. This drive is available on either self-propelled or pulled-type machines.

For power-driven reels a range of sprocket sizes is provided to compensate for different ground travel speeds. Some manufacturers provide adjustable reel slats so that the inclination of the slat can be adjusted to brush crooked-neck varieties of grain onto the platform, thereby eliminating loss of heads which would otherwise be hooked on the reel and carried over by it. Such losses can also be decreased by widening the reel slats with additional boards, wide screen, or canvas or by increasing the height of the platform backstop. To minimize losses in harvesting short crops, belt wipers on the reel slats or small diameter reels are sometimes used.

Special feathering or pickup reels with flexible steel fingers attached to the slats and adjustable as to angle are available for special crops and field conditions. The operator usually has adequate control over height of cut, which generally ranges from 2 to 36 inches. Some manufacturers furnish a low-cut or floating bar for lodged grain or for a crop with low-growing pods. Such a bar is designed to float on the ground under the regular cutter bar and cut the grain, leaving a stubble of not more than 1½ inches.

Ordinarily the cutter bar should be operated at a height that will miss very few heads but still cut enough straw to provide a cushion for the grain to prevent excessive shattering.

The elevation of platform and cutter bar on self-propelled machines and the height of pull-type combine platforms are controlled either hydraulically or by an electric system.

Thresher

FEEDER

The feeder on the conventional-type combine receives the crop from the header and conveys it to the cylinder. Some device, usually in the form of a beater, or slatted conveyor, is used to force the crop down against the conveyors and back into the cylinder (fig. 3).

The conveyors should require little special attention. They should, of course, be kept in good mechanical condition. Broken slats should be replaced immediately to avoid uneven feedings and possible plugging of the cylinder. The drag may pull material under the feeder if the proper tension on the chains is not maintained or if the feeder board becomes warped or dented. Pitching heavy tools or parts of the combine into the feeder house while transporting the machine may dent the feeder board sufficiently to allow straw to get under the drags. The chains must also be even in length for smooth performance.

CYLINDER AND CONCAVES

The beating action of the cylinder and the rubbing action between the high-speed cylinder and the stationary concaves remove the seed from the head or pod. Grates, either between the concaves or back of the cylinder, or both, are usually provided to separate as much of the threshed seed as possible from the straw at the cylinder.

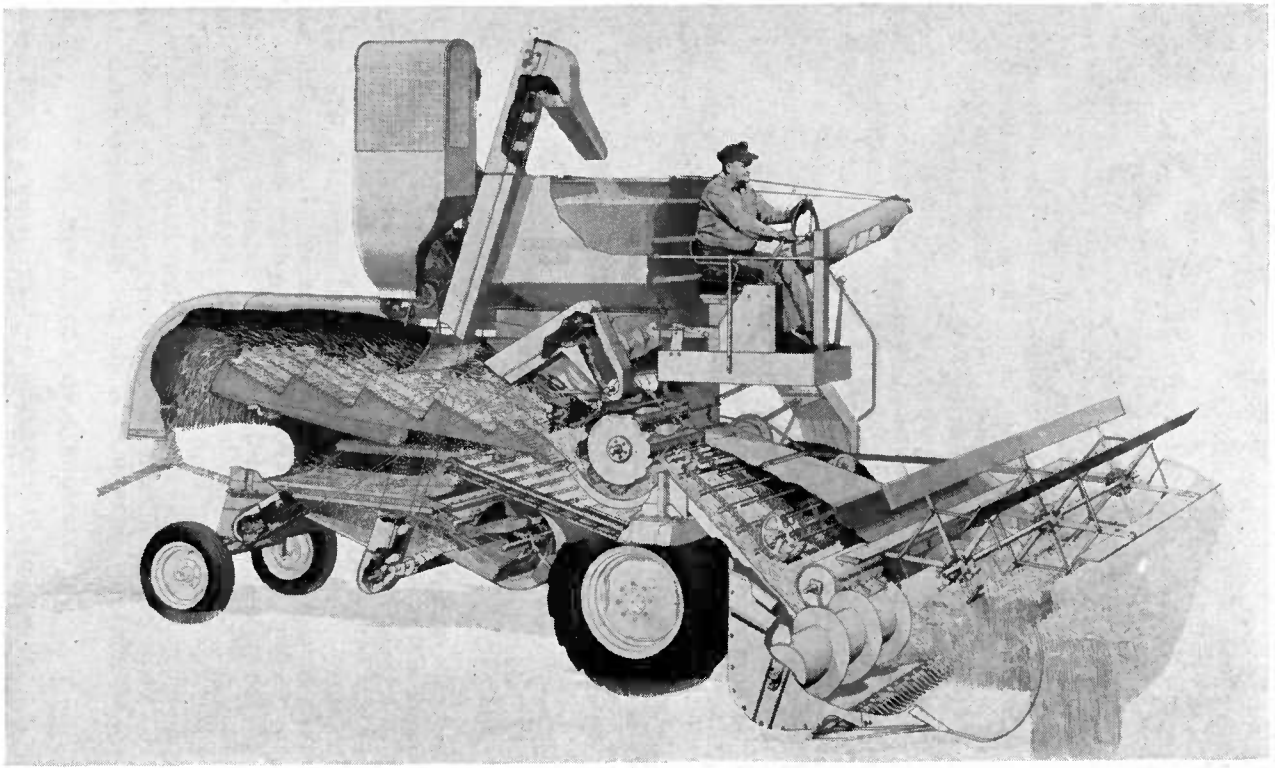

FIGURE 3.—Cutaway view of self-propelled combine showing paths of straw and grain.

Threshing cylinders in combines may be classified as rasp-bar, angle-bar, and spike-tooth types. Rasp-bar and angle-bar cylinders are more common than spike-tooth cylinders.

The rasp-bar cylinder (fig. 4) has corrugations that generally run in opposite directions on alternate bars and rub the crop against the concaves. Corrugated bars, similar to those on the cylinder, or smooth bars may be used as concaves. Rasp-bar cylinders are usually driven at a higher speed and are generally longer than spike-tooth cylinders. As they do not break the straw so badly as the spikes, they make it easier to separate the grain from the straw.

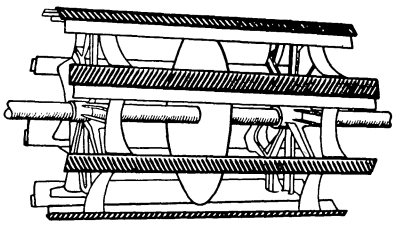

FIGURE 4.—Rasp-bar cylinder.

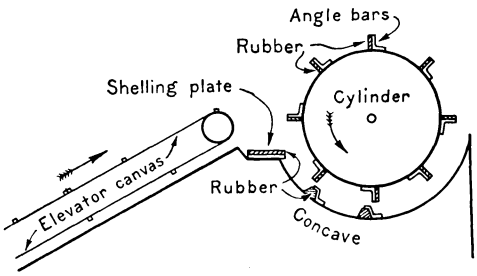

FIGURE 5.—Angle-bar cylinder with rubber-faced bars and rubber concaves. The cut grain moves back and upward from the cutter bar to the cylinder, which is the entire width of the cutter bar.

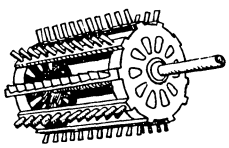

FIGURE 6.—Spike-tooth cylinder.

The angle-bar cylinder is used only on combines in which the cylinder is the width of the sickle and the cut crop is conveyed to the cylinder in a thin layer. Combines of this type use slightly spiralled angle-iron bars faced with rubber. The concaves also are rubber, as illustrated in figure 5, and are held in place by clamps. This type of cylinder is usually driven at a higher speed than either of the others. The chief advantage claimed for it is that it does not break or chop up the straw. This simplifies the cleaning operation, lessens the possibility of clogging, and provides unbroken straw for feed or bedding.

The spike-tooth cylinder (fig. 6) probably has a higher capacity per unit of width than either of the other types, because of the combing

action of the teeth. In feeding such a cylinder, the unthreshed crop is more or less cramped or squeezed in getting to the cylinder but is combed out as it passes between the cylinder and the concave teeth.

The cylinder of each combine is designed to operate within a certain range of speed and varies with the different makes and models of combines. The speed of the cylinder is rated in revolutions per minute and ranges from a low of about 300 r. p. m. to a high of 1,800 r. p. m.

Changing the governor speed of the engine for slower or higher cylinder speed is not recommended as this affects the efficiency of all the other units of the combine. Combine manufacturers provide variable speed control for the cylinder with V-belt variable-speed drives or sprocket changes on the drive.

Before combines are taken to the field, speeds of engine output shaft, beaters, and racks or conveyors should be checked to comply with the speeds included in the operator's manuals that accompany the machines. Speeds of revolving shafts can be readily checked with a revolution counter.

Most manufacturers of combines with rasp-bar and spike-tooth cylinders make provision for adjusting the concave to the cylinder. Ordinarily, with rasp-bar cylinders, the narrowest spacing between cylinder and concaves is satisfactory. If the grain cannot be threshed from the heads, the cylinder speed should be increased. If wider spacings cause straw to be broken excessively and grain to be cracked, cylinder speed should be reduced. Uneven settings of the rasp-bar cylinder contributes to cracking of grain as does excessive cylinder speed.

With the angle-bar cylinder, adjustments are provided for setting the cylinder forward or backward in the housing. For heavy crops the cylinder may be set forward and in extremely light crops it may be set backward, although these adjustments are seldom necessary.

Cylinder teeth striking closer to the concave teeth on one side than on the other, either because of improper setting or because of end play in the cylinder, are shown in figure 7, *A*. This may crack grain on one side and allow unthreshed grain to pass on the other. Bent teeth also may cause cracking in this manner. The concaves in figure 7, *B*, may be low enough to allow unthreshed grain to pass, and the close setting in figure 7, *C*, may cause cracking, as well as excessive breaking and chopping of the straw. Adjustments for uniform spacing (fig. 7, *D*) usually give the best results except when the crop is easy to thresh. Under such conditions the position of concave illustrated in figure 7, *B*, may be best.

Each part of the combine must be in good condition and carefully adjusted to do the best threshing. Poor threshing is invariably caused by improper concave setting, badly worn or bent concave and cylinder teeth, or too low cylinder speed. Dry and well-matured grain is usually comparatively easy to thresh, but under certain conditions very dry grain may crack badly.

Cracking is usually caused by excessive cylinder speed, a bent or loose cylinder or concave bars, the return of an excessive amount of threshed grain to the cylinder with the tailings, improper concave setting, and too little clearance between cylinder and concaves.

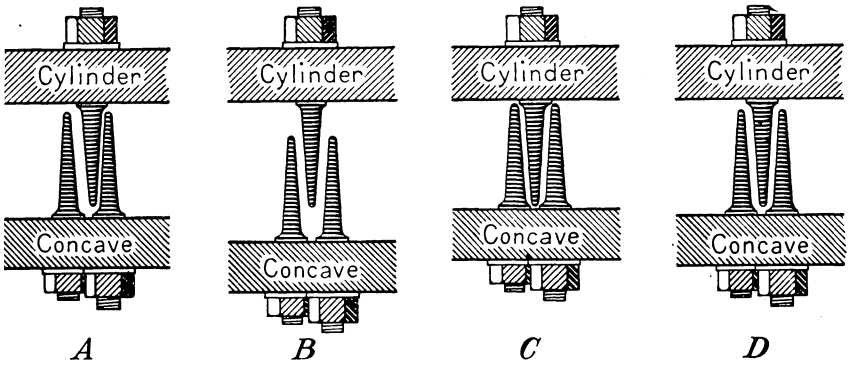

FIGURE 7.—Spacing of cylinder and concave teeth: *A*, Cylinder teeth not centered; *B*, concaves low; *C*, concaves high; *D*, uniform spacing.

Spike-tooth cylinders will crack grain if there is too little clearance between cylinder and concave teeth or excessive play in the cylinder shaft, if teeth are bent or loose, or if too many concave teeth are used. Also teeth may be set too high to prevent badly chopped straw and clogged sieves. Bad threshing may also be caused by badly worn concave and cylinder teeth, which also increase power consumption.

For tough grain it may be necessary to use all of the concave teeth. All other adjustments should be attempted, however, before additional teeth are put in, since it is always best to use as few teeth as will thresh all the grain from the heads.

Soybeans, grain sorghums, and some similar crops are frequently cracked when the cylinder is run at rated speed, regardless of the crop conditions and the adjustments of the other parts of the combine. Best results are possible with such crops, especially beans, only within a narrow speed range. Manufacturers provide various adjustments for operating their combines within this range. Suitable pulleys, sprockets, or gears that will reduce the cylinder speed without changing the speed of the other moving parts can be obtained for some machines from the manufacturer. Some combines, usually those with a V-belt drive, are provided with speed-changing devices. These permit altering the speed of the other combine parts to compensate for a lower cylinder speed. This is done by moving one side of a V-pulley in or out when stationary, by adjusting the bolt, or by regulating a movable plate one way or the other with a screw arrangement that increases or decreases the pressure on the plate.

Separator

A beater is usually provided just back of the cylinder for stripping the straw from the cylinder and deflecting it down against a conveyor. The loose grain is also beaten down, and, since it is heavier than the straw, considerable separation takes place at this point. The straw conveyor performs two functions—it moves the straw back away from the cylinder and agitates it to shake out threshed seed as the straw is being moved to the rear of the machine for dumping on a spreader, straw dump, or directly on the ground.

In separating the threshed grain from the straw, straw walkers, slatted drag conveyors with beaters, or a combination of these types of conveyors are generally used. Straw walkers kick the straw upward and backward in moving it from the rear of the cylinder to the rear of the machine. In this type of conveyor grain shaken from the straw is returned to the chaffer on a grain pan or on a trough attached

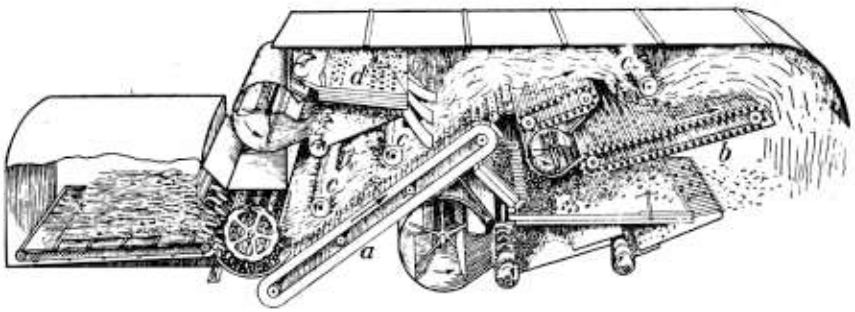

FIGURE 8.—Rotary or drag-type straw conveyor with beaters. The grain from the chaffer is elevated to the recleaner; from there it is conveyed to the bin, sacker, wagon, or truck: *a*, Straw and grain conveyor; *b*, straw conveyor; *c*, beater; *d*, recleaner.

to the walker. The drag-conveyor type (fig. 8) has beaters and agitators for agitating the straw as it is moved toward the rear of the machine, the return acting as a conveyor for dragging the grain back to the chaffer. A drag conveyor is usually provided for taking the grain to the chaffer as it falls through the rack. Another type of straw

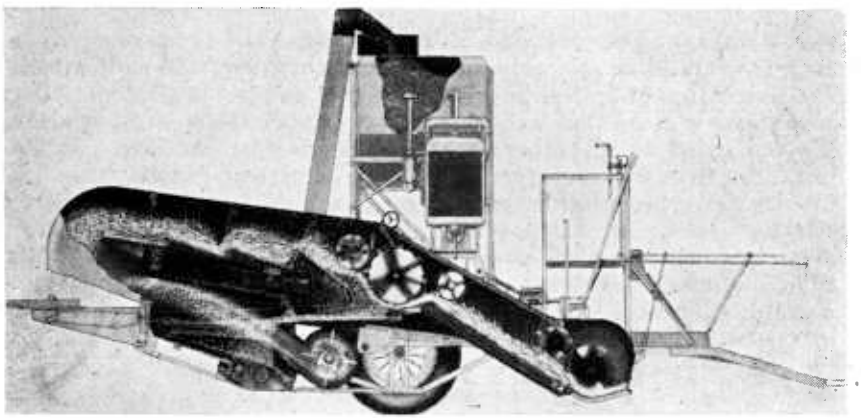

FIGURE 9.—Rotary type of straw rack.

rack in common use is the rotary type shown in figure 9. The straw is thrown backward with a rotary or pitching motion imparted by crank arms.

The threshed seed, together with short pieces of straw, weed seed, chaff, and unthreshed heads or pods is deposited on a chaffer in the lower shoe by means of a grain carrier. This chaffer may be mesh wire, a lip sieve, an adjustable sieve, or a combination of such units, and is

subjected to vibration and air blast. The chaff, with other such light foreign material, is blown out and the unthreshed heads or pods are moved to the rear, where they fall into the tailings auger and are conveyed back to the cylinder for rethreshing.

No changes from the rated speed of straw racks, conveyors, fans, sieve vibration, or other moving parts should be attempted except as recommended by the manufacturer.

If threshed grain is carried out with the straw, it may be because of the excessive speed of the moving parts, an unduly strong air blast on the chaffer, overloaded straw agitators and chaffer, or bent, broken, or stuck baffle boards back of the cylinder. Excessive speed on the straw conveyor and sieves tends to discharge the straw and chaff before the grain is shaken out. If the separator is found to be running at rated speed, decrease the air blast slightly on the chaffer by adjusting the fan blinds.

Grain may be carried out with the chaff when the air blast is insufficient to keep the material on the chaffer fluffed, or "alive." When a considerable quantity of straw is cut it may be necessary to reduce the rate of travel or decrease the width of the swath to prevent overloading the straw conveyors and chaffer. For best results in cleaning, the chaffer should be adjusted to remove as much foreign material as possible without overloading. If the chaffer is overloaded the quantity of material may be reduced by changing the size of the openings in the straw walkers by the use of smaller mesh wire or by other means, depending on the machine.

Cleaners

The threshed seed, together with weed seed, short pieces of straw, and other foreign material not removed by the chaffer, falls on a lower sieve for further cleaning by agitation and air blast or is conveyed to another cleaner known as a recleaner or upper shoe. From the lower sieve or the recleaner, as the case may be, the grain is conveyed to the grain bin, bagging attachment, or directly to a wagon or truck. Some manufacturers provide an additional cleaner, generally known as a rotary weed screen, for removing small weed seed from the grain. Screens are also provided in some conveyors for disposing of weed seed and in others for separating threshed grain from the tailings.

The quantity of foreign material in grain has a decided bearing on its grade and market value. Weed seeds, dirt, and trash must ultimately be removed. Effective cleaning often requires considerable skill but is usually under the control of the combine operator. Proper cleaning depends not only on the adjustments of the sieves and fan but also on the use of proper screens and the effective operation of the entire machine.

As much wind should be used on the sieves as is possible without blowing the grain out or into the tailings auger. Oats, for example, are very much lighter than wheat and consequently require less wind. Adjustments are provided for regulating the blast to suit practically all conditions. Be sure that the fan supplies air evenly along its entire width. If one blind is opened wider than the other the distribution will not be uniform and will tend under some conditions to blow grain out on one side and leave the chaff and light material with the

grain on the other. It is usually better to reduce the fan speed than to close the blinds completely.

Sieves vary widely with the type and make of machine. In some cases sieve adjustment is provided to take care of different kinds of grain as well as variations in crop conditions, and in others extra or special sieves are furnished. The most common types found in combines are shown in figure 10. The term "sieve" usually applies to the round-hole, oblong-hole, woven-wire, and lip types. Some of these, however, may be used as screens. In this connection a sieve is used to let the grain through but to exclude certain foreign material, whereas a screen excludes the grain but lets small weed seed and dirt through.

Cleaners and recleaners provided on some machines will usually do their best work at or below rated capacity. They are designed to take care of average conditions, and if taxed beyond this capacity on account of weeds, excessive chopping of the straw, or overfeeding (rate of travel too fast for the condition of the crop) they will either throw the grain out with the straw and chaff or clean it improperly.

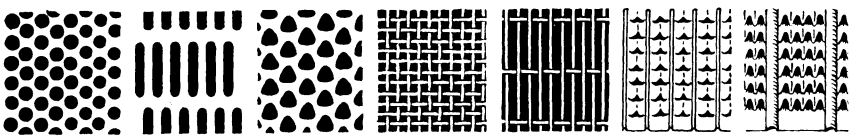

FIGURE 10.—Types of sieves commonly found in combines: *A*, Round-hole; *B*, oblong-hole; *C*, cardioid-hole; *D* and *E*, mesh-wire; *F*, lip; *G*, adjustable.

Uniform feeding of grain over the entire width of the cleaner is also essential. The overloading of sieves becomes very evident, especially in high-speed power takeoff combines, when a weedy field is encountered or one in which the crop is lodged and it is necessary to handle a large mass of straw. Under such conditions, shifting from high or from plow speed to low gear on the tractor has been known to reduce by as much as 50 percent the quantity of grain carried out with the straw.

On machines provided with adjustments for changing speed, length of stroke, and angle of sieves it is well to remember that optimum performance is possible within a fairly narrow speed range. If the sieve vibrates too fast many of the kernels will bounce off or have insufficient time to get through the openings, and if the rate of vibration is too slow the material will blanket the sieve.

In setting adjustable sieves, servicemen often take a handful of grain and throw it on the sieve when the machine is not in operation to see whether the seed will fall through readily. If the seed is retained, it is necessary to open the sieve enough to permit falling through. In this way fine adjustments can be made quickly after the machine has been started.

Tailings Elevator

The material handled by the tailings elevator comes from a point back of the shoe sieve. Examination of this material is the best means for determining how well all parts of the combine are working.

If the examination shows (1) material chopped too fine by the cylinder, there are too many concaves or concave teeth; (2) too much chaff, the sieve is improperly set; (3) grain only partially threshed out of the head, the clearance between the cylinder and the concaves should be adjusted; and (4) foreign material in the tailings, the air blast should be increased.

The quantity of material carried by the tailings elevator, which should be a minimum, governs the setting of the whole machine.

Attachments

Auxiliary equipment for the combine has been devised and is used to meet some of the various harvesting conditions in different parts of the country. Such attachments are usually extra and may be obtained for some machines if the harvesting and threshing requirements justify additional expenditure.

FLAX-ROLL ATTACHMENTS

Flax-roll attachments are available for most combines. They consist of 2 rubber-covered rollers, or 1 rubber-covered roller and 1 steel roller. One roller is mounted on springs.

These rollers are installed directly in front of the threshing cylinder. As the flax passes through them, the bolls are crushed for easier threshing. Peripheral speed of the cylinder can be lower with the attachment than without it, since it maintains an even and positive feed of material to the cylinder.

A flax-roll attachment in a combine makes it possible to have a larger opening between the cylinder and concave. This cuts down the breaking up of the straw and reduces the amount of chaff going through the machine.

Flax-roll attachments will work satisfactorily for most other small grains and grass seeds.

GRAIN-BIN, WAGON-HITCH, AND BAGGING ATTACHMENTS

A grain-bin, wagon-hitch, or bagging attachment can be obtained for practically all machines. Grain bins for the larger machines usually hold about 65 bushels; those for the smaller sizes, 20 to 40 bushels. These bins are emptied either by gravity or by an elevator and conveyor to a wagon or truck. When the wagon hitch is used, a wagon is attached to and drawn alongside the combine. In case the motive power is insufficient for both the grain wagon and the combine, the wagon may be pulled as a separate unit. A bagging attachment can be used in lieu of either grain bin or wagon hitch if desired. The bagging attachment usually consists of grain spouts and a platform with dumping device where the grain can be sacked and the sacks dumped on the ground.

WEED SCREENS

Foul seeds that pass through the weed screens should be collected in sacks instead of being scattered in the field. This is exceedingly important because it helps reduce weed infestation.

PLATFORM EXTENSION

Most combines have sufficient capacity for handling a considerable quantity of straw. When the crop is light or very little straw is cut with the grain a platform and reel extension may be attached to the outer end of the platform to increase the width of the cut. Using this extension under normal to heavy crop conditions will overload the combine. This equipment is attached directly to the platform and reel, but the original sickle is usually replaced by one of suitable length for the longer platform.

SICKLES AND PICKUP GUARDS

Sickles and guards designed for special crops or field conditions are available for some combines. Pickup guards for use in down and tangled grain and in rank-growing soybeans can also be obtained.

WEED SEED CLEANER

For removing small weed seeds, especially in heavily infested crops, a rotary-type seed cleaner is available for practically all types, makes, and sizes of combines, old or new.

This device may be mounted either on the bagger or on grain-tank machines. It is provided with special screens to adapt it to practically any crop or harvesting condition.

FLOATING CUTTER BAR AND TINED REEL

To handle low-growing and tangled crops, a floating cutter bar and tined reel are available for most makes and sizes of combines. The cutter bar is designed for extremely low cutting. The reel is adjustable horizontally and vertically. Its bats are fitted with long spring fingers or tines, which can be angled, according to the need of the crop, to pull the cut material onto the header platform. Special lifters are also available for harvesting peas. They lift the vines high enough to prevent cutting the pods.

For combining dry peas in the Pacific Northwest, where combines equipped with draper-type conveyors are used, a number of devices have been developed for facilitating the movement of the cut material along the draper into the feeder house. One is a steel strap floating on the platform draper. This strap is of ¼- by 1-inch iron cut to match the length of the header and is fastened near its outer end, so that the peas which are picked up at the outer end tend to be dragged under the strap and those picked up near the middle are thrown on top of the strap but the entire mass is knitted together.

Another and more effective device is called the "Chinaman." This unit consists of large diameter sheet-metal power-driven disks fitted at the edge with flexible steel fingers and mounted along the length of the header to revolve in a vertical plane. The peripheral velocity of the unit is the same as that of the draper speed. It acts as a positive feed to move the material with the draper.

STRAW SPREADER AND BUNCHER

A straw spreader is generally used when the straw is not needed for feed or bedding and it is desirable to have it scattered uniformly

over the field. When the straw is to be saved, a buncher can be used to dump it in piles, or a conveyor to windrow it. The straw from the buncher is usually dumped by a trip rope extending to the operator's platform. If the buncher is overloaded, straw will accumulate in the separator and clogging will invariably result. If a spreader, buncher, or conveyor is not used, the straw is left in windrows behind the combine.

WINDROW HARVESTER AND PICKUP

Windrow-harvester and pickup attachments can be had for most combines. With this auxiliary equipment the crop can be cut and laid in windrows, picked up when dry, and threshed with the combine. Fields badly infested with weeds and crops that do not ripen uniformly have been harvested successfully by this method. Under ordinary conditions the weeds and green grass dry out in 2 to 8 days when windrowed, enabling the combine to do a better job of threshing and cleaning. The header of some machines is removed, mounted on a carriage, and used as a windrower or swather. A special windrower is provided by other manufacturers. The pickup attachment is attached to the regular header on the combine or supplied as a unit that is attached to the combine in place of the regular header.

In some areas there has been appreciable spoilage of grain because its moisture content was too high when harvested, or because of moisture imparted by weeds. Drying the harvested grain, however, before putting it into storage, particularly in the humid States, will minimize this loss of spoilage (see p. 18). Losses can also largely be avoided by combining from the windrow.

OPERATION

Because of the wide variation in crop and harvesting requirements, it is impossible to give definite rules for combine operation that will be adequate under all conditions; yet many difficulties may be overcome by following general directions.

In making adjustments or working about the combine, stop the engine. Keep hands and clothes away from moving parts, especially the cylinder and sickle. Do not put gasoline in the tank while the engine (combine or tractor) is running. Be sure that the exposed parts of the power takeoff shaft are properly shielded with the guards provided for that purpose. The guards supplied by the manufacturers should always be used.

Starting a New Combine

Before starting a new combine, go over the machine thoroughly to see whether all bolts and nuts are tight. To avoid serious damage, be sure that no tools are left in the machine or on the platform canvas. Turn the cylinder and other moving parts a few times by hand to see that everything is in good order and free to move. Trouble with a new machine is in most cases due to improper or careless setting-up or lack of lubrication. Be sure all chains and belts are installed correctly, as disastrous results have occurred when some parts were driven in the wrong direction. Examine all slip clutches and make sure that none are stuck.

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A new combine should not be subjected to its working load until it has been run idle for several hours. Run the engine at low speed for an hour or more before throwing the combine in gear. Run the combine at about half speed for at least an hour and at full speed for about the same length of time before starting the machine in the field. Examine the bearings frequently and keep them well lubricated. In case water in the radiator should accidentally run low and the engine overheat, shut off the ignition and turn the engine over by hand while the radiator is being filled. Pour water into the radiator slowly, as a cracked cylinder block may result from cooling the motor too quickly.

Role of the Tractor Driver

The tractor driver plays an important part in the successful operation of the combine. The machine is so designed that under average conditions each part will work at optimum capacity. As field and crop conditions change, however, some part may be overloaded. If heavy down grain or green weeds are encountered, the ground speed or the width of cut should be reduced. It is also important that the crop be fed to the cylinder at a steady, uniform rate and that a full swath be taken whenever possible for maximum daily capacity. Good tractor drivers, under ordinary conditions, can regulate the ground speed by the sound of the engine so that the combine will operate at optimum capacity. Ground speed should never be controlled by the throttle on power takeoff drive machines. This has the effect of reducing the cylinder speed and that of the other parts of the combine. Shift gears instead to a lower travel rate.

Combining in Green Weeds

A combine is subjected to unusual strain when operating in a crop heavily infested with green weeds, for their high moisture content makes them comparatively heavy. In addition to the difficulties encountered in saving the seed under such conditions, mechanical weaknesses may occur and result in breakages or at least delays. It is important, therefore, that the machine be in good condition and properly adjusted. In fields rank with green weeds it might be preferable to use the windrow method (see Windrowing, p. 22) and waste the tailings where small patches of green weeds are encountered.

To overcome difficulties with green weeds, many operators spray chemicals by airplane to kill and dry their tops from 1 to 2 weeks before the grain is ready for harvest.

Small pieces of green weeds are hard to separate from the crop seed. Tailings should be reduced to a minimum because the weeds will be chopped up into finer pieces each time they are returned to the cylinder. Be sure that the machine is run at rated speed and that a sufficiently strong blast of air is supplied to lift the material as it passes over the chaffer. If these precautions are not taken the weeds tend to form a blanket over the chaffer and invariably choke the machine.

Lowering the tailboard will doubtless facilitate quick disposal of green weeds, and although some grain is lost, it may be justified. Tail rakes or sieve extensions, permitting the return of much material, should be replaced by special extensions having more closely spaced tines to reduce the quantity of material falling through. The same

principle may be used in the straw rack by installing fingers to reduce the quantity of material returned. Free passage of the green material may be aided by fastening back the check flap above the straw rack.

The tractor driver can assist by watching the material entering the feeder house and reducing the width of the swath or the rate of travel if weeds are abundant. Combining in a field rank with weeds is shown in figure. 11. The header operator, too, can assist materially in preventing trouble by operating with the cutter bar above the weeds, though some grain will be missed. Before starting on a badly infested field it might be well to survey it to determine which parts will be worth combining. The rest can be cut later by some other method.

FIGURE 11.—Harvesting a weedy field of oats.

Combining Lodged Grains

The combine is generally recognized as particularly effective in harvesting lodged or down crops. The part of the crop gathered, however, will depend upon the care and precautions taken. Under such conditions savings may be effected by pickup guards, and on some machines by low-cut bars. Pickup reels on which the slats are provided with steel fingers are also available. These are especially adapted to lifting down crops and they work best when harvesting in the direction of lodging.

Where lodging is complete the header must be set at its lowest position, which means that a large quantity of material will go through the machine if a full swath is taken. The ground speed should be watched carefully and kept low enough to permit proper handling of the tangled mass by the combine. The header operator should be constantly on the lookout to prevent the picking-up of clods, rocks, or other foreign material.

When most of the crop has lodged in one direction, cutting operations are greatly aided if the machine travels in the opposite direction,

although cutting in only one direction is rarely economical because of the empty travel involved.

In fields of lodged grain the reel may be subjected to unusual strain. If so, it would be well to reinforce the slats with wooden strips. The reel should be set lower and several inches ahead of the sickle. When the reel is set low, canvas belting is sometimes fastened at the outer edge of the reel slats to brush the cut grain back onto the platform without danger of breaking the slats. In adjusting the reel care should be taken to keep it parallel with the sickle. A slower travel rate or a narrower cut is often necessary to save lodged grains.

Dry Grain Essential

Ripe, dry grain is one of the first essentials for the successful operation of the combine. This is true for all grains except rice. Green or damp grain not only interferes with the threshing and cleaning operations but has a decided influence on the market value and keeping qualities of the grain. Tough straw has a tendency to clog the machine by winding on the cylinder and other moving parts, especially when they are driven below normal speed. Small particles of tough straw are difficult to remove from the threshed grain because the straw is much heavier when damp or green. In harvesting most cereal grain the combine should not be started until the grain is dead ripe, which is usually 7 to 10 days after it is customary to begin harvesting with the binder. If the threshed grain feels damp or is easily dented with the fingernail, the moisture content is generally too high for safe storage.

No accurate, simple, and inexpensive grain-moisture tester suitable for general farm use is available. Sometimes, however, local grain elevators will make moisture tests, the results of which are helpful in determining when to start the combine. The maximum moisture content at which different crops may be stored safely depends in part on atmospheric conditions, storage facilities, foreign material in the grain, whether they are harvested in bulk or in sacks, and whether the crop is for seed purposes or for market. Standards for market grades of various crops prepared by the Grain Branch of the Agricultural Marketing Service can be used as a guide.

Winter wheat, rye, grain sorghums, rice, emmer, spelt, and similar grain crops containing 14 percent moisture or less, are considered dry enough for safe storage or transportation; spring wheat, oats, and barley containing not more than 14.5 percent; flax with not more than 11 percent; and soybeans having not more than 15 percent. The maximum moisture content for safe storage of buckwheat, field peas, and edible beans has not, so far as is known, been definitely established. Buckwheat and field peas, however, are acceptable on the market if they contain 16 percent moisture, and edible beans if they contain 18 percent. Many of these crops, especially beans, peas, and buckwheat, when stored, should have a moisture content lower than that indicated, especially if they are to be used for seed.

Grain Drying on the Farm

Grain drying by mechanical ventilation removes many of the hazards of harvesting and storing crops. Such drying is valuable not only for emergency handling of high-moisture crops, but also as part

of a regular crop-management program. Controlled drying fits in with modern production, harvesting, and handling methods. It overcomes the problems presented by the use of grain combines—equipment that gets the crops out of the field quickly but often dangerously wet. The availability of electric and gasoline-engine power and use of such power in driers of modern design makes mechanical ventilation possible.

Where mechanical drying systems are used, small grains can be:

1. Stored safely.
2. Marketed without a moisture discount.
3. Harvested as soon as mature, thus reducing the chance of storm damage while the crop is drying in the field.
4. Harvested faster, by operating combines early in the morning and late at night.
5. Combined directly, without windrowing.
6. Saved even in wet harvesting weather, when, because of late seeding or poor growing weather, the crop must be harvested although it contains a high percentage of moisture.

Drying grain by mechanical ventilation is explained in United States Department of Agriculture Leaflet 331, Drying Shelled Corn and Small Grain with Heated Air, and Leaflet 332, Drying Shelled Corn and Small Grain with Unheated Air. Copies of these publications are available from county agricultural agents, the Extension Service agricultural engineer at State colleges, or from the Office of Information, United States Department of Agriculture, Washington 25, D. C.

The following advantages and disadvantages for both unheated- and heated-air drying may be helpful in considering a drying setup.

Heated-Air Drying

Advantages:

1. Can dry wettest grain.
2. Can dry regardless of weather conditions.
3. Short drying time.
4. High drying capacity per fan horsepower.

Disadvantages:

1. Higher initial equipment cost.
2. Expense for fuel.
3. Some fire hazard.
4. Considerable supervision required.

Unheated-Air Drying

Advantages:

1. No expense for fuel.
2. No fire hazard.
3. Lower initial equipment cost.
4. Little supervision required.

Disadvantages:

1. Dependent on weather conditions.
2. Slow drying rate; usually several weeks.
3. With prolonged drying, grain may be damaged by mold growth.

Transporting the Combine

In transporting large machines the header platform is usually disconnected from the side of the machine, mounted on a transport truck, and pulled behind the combine. This reduces the overall width by approximately the length of the header platform. The platform on some of the smaller combines may be folded up and back against the machine. Five-foot and smaller machines can pass through a 12-foot gate without being dismounted. With the increased use of com-

bines on small farms and in a wide variety of crops, ease of transporting the machine from field to field is of great importance. This feature makes it possible to use combines in one field more than once each season and to transport them over narrow country roads.

CARE OF THE COMBINE

Combine manufacturers usually furnish a manual giving specific instructions on the care and operation of their machines. This manual should be studied, as the information gained may result in a saving of time, labor, and grain.

Careful inspection and maintenance procedures can do much to insure trouble-free and economical harvesting. Important maintenance operations include keeping belts and chains in proper tension, removing dirt and chaff from radiators, maintaining clean oil in hydraulic systems, cleaning air cleaners on engines, freeing straw racks and sieves of beards and dirt, and lubricating properly.

Repairing

Successful combine operators appreciate the importance of getting the machine in working order before harvesttime. If the machine is new it should be "broken in" (p. 15) as soon as possible, because any trouble that develops can be remedied early and valuable time may be saved when the crop is ready for harvesting. Combines that have been used during previous seasons should be overhauled several weeks before harvest actually begins, repaired, and run for a short time. Some adjustments must be made in the field, but it is possible to have all parts in such condition that the necessary adjustments can be made quickly and accurately.

Oiling

Manufacturers' printed instructions for the proper lubrication of their machines should be followed because the life of the machine depends on it. Before oiling a new machine, clean the paint and dirt from all the bearings and oilholes. On bearings using hard oilers force the grease in until it appears at the ends of the bearing. This forces out any dirt and insures complete lubrication of the bearing. Fill the oil cups until the space around the shaft is completely filled with oil. Drive chains should not be oiled if sand or other abrasive substances are likely to accumulate on them. Chaff and particles of dust from the grain and straw, with the possible exception of those from rice, are not abrasive.

Caution.—To avoid accident, no part should be in motion during the oiling.

Belts and Canvases

When the combine is to be left standing overnight exposed to the weather, remove the platform canvas and all belts or protect them from rain and dew. The canvas and belts can be placed on the straw racks in the rear of the machine or they can be covered with old binder or header canvases. If a tarpaulin is available, cover the

entire machine. If the platform is held in position by springs it should be set, when not in use, in such position as to relieve the tension on the springs. Straw and chaff should not be left in the combine, as such material retains moisture and may cause some of the metal parts to rust. The greater part of the straw and chaff can be discharged by running the machine empty for a few minutes after finishing for the day.

Housing

Immediately after the harvest the combine should be cleaned thoroughly both inside and out and housed in a shed or barn under a good roof. Trash and dirt retain moisture and will cause metal parts to rust and wood parts to rot. All belts and canvas should be removed, kept dry, and protected from rodents. The machine (exclusive of wearing surfaces) should be painted, and the metal parts coated with a heavy oil. Use linseed oil on the wood parts only. While cleaning the machine inspect all parts and list those needing repairs. Such a list will be useful in ordering replacements and may save delay during the next harvest season.

If it is impossible to house the combine, remove all belts and canvases and store them. Remove the reel and hang it up in a shed to prevent the slats from being broken or warped. Paint and oil the machine, as described above. If a tarpaulin is used, tie it down in a manner to prevent the formation of pockets and low places where water might collect and eventually soak through and damage the machine.

Special attention should be given to the engine, as it is the most expensive part of the combine. Remove air and exhaust stacks and cover the engine to keep water out of the cylinders. Special instructions given by the several manufacturers of combines vary somewhat as to the exact procedure that should be followed at the end of the harvest season in housing machines equipped with engines, but the following recommendations are essential:

1. With a brush remove the dirt and grease from the exterior and clean it with gasoline or kerosene.
2. Drain the crankcase, refill it with fresh oil, and run the engine a few minutes to coat the cylinder walls and all the bearings with a film of fresh oil.
3. Remove the spark plugs and pour approximately half a pint of cylinder oil (not steam cylinder engine oil) or 2 or 3 tablespoonfuls of castor oil in each cylinder, turn the engine over a few times and replace the spark plugs.
4. Drain the cooling system and engine block and leave the drain cock open.
5. Drain the fuel system if the machine is to be stored where gasoline may constitute a fire hazard.
6. Cover the engine to exclude water, dust, and dampness.

Ordering Repairs

When ordering parts give the make, model, size, and number (if any) of the machine as well as the description and number of each

part and the quantity needed, because the parts on different sizes and models are not always interchangeable. It is good practice to give the date when the machine was purchased new or the serial number of the machine, as this will help to identify the model.

WINDROWING

As combine operators and owners become more familiar with their machines and with the ripening characteristics of crops on which the combine is used, there is generally less need for windrow and pickup attachments. In spring wheat and oat-growing areas their use is common, whereas in winter wheat areas direct combining seems to be satisfactory. A windrower is shown in operation in figure 12.

For best results in windrowing, the windrow should be supported and held above the ground by the stubble. If this is not done, wet weather may damage the crop to a greater extent than if it were left standing in the field. In weedy fields, however, where the stubble will support the windrow, and for crops that do not ripen uniformly, the windrow method can be used to advantage. For proso (hog millet), alfalfa, clovers, and certain varieties of beans and peas this is the usual method.

FIGURE 12.—Windrowing.

A mower followed by a side-delivery rake or a binder is sometimes used when regular windrowing equipment is not available, though this practice is not generally recommended. In such cases judgment should be exercised in making the windrows, to assure a uniform feed to the combine in picking up and threshing the crop. In general, each windrow should contain about the same quantity of straw as would be handled in straight combining. For example, if the combine used in picking up the crop is designed for a cutting width of 12 feet, the windrow should be formed from a swath not to exceed this width, except possibly for oats and for other crops having light straw.

When the regular windrower or swather is used, the combine with pickup attachment should be driven along the windrow in the same direction as that in which the crop is cut. When this is done, the straw is more likely to be fed to the cylinder head first. In picking up the windrow it is also important that the ground speed and the speed of moving parts be such as to feed the crop to the cylinder at a uniform rate.

CROP CHARACTERISTICS AND COMBINE PROBLEMS[2]

The time of harvesting or stage of maturity at which to harvest crops with the combine for best results is of extreme importance. New varieties are constantly being developed. Yield, quality, and resistance to diseases and insect pests are usually the primary objectives of plant breeding. In recent years much consideration has been given to plant characteristics that facilitate harvesting with mechanical equipment.

The Wheatland, Colby, Westland, Plainsman, Caprock, Midland, and Bonita grain sorghums were developed by the Field Crops Research Branch and cooperating State agricultural experiment stations to obtain varieties suitable for harvesting with a combine. The Martin variety, selected by a farmer from the Wheatland variety, is a widely grown combine type. New varieties of oats, wheat, and barley having short, stiff straw have been developed for combine handling.

Farmers can overcome many difficulties frequently encountered in harvesting with the combine by giving special attention to the ripening characteristics of the crops and to weed control. Useful information as to varietal characteristics of the crops grown in a particular part of the country can usually be obtained from State agricultural colleges.

Wheat

Characteristics desirable in wheats to be harvested with combines are chiefly strength of straw and resistance to lodging, uniformity of ripening, nonshattering seed habit, and erect heads of uniform height. Seldom, however, are all desirable characteristics found to a marked degree in one variety. Difference in maturing dates is especially important in selecting early-, medium-, and late-maturing varieties for a continuous harvest with a minimum of delay or overlapping. Varieties susceptible to insect injury and disease should be avoided as far as possible. The use of pure seed is helpful in attaining uniformity of ripening.

Ordinarily wheat varieties are grown because of their adaptability to the locality, and many of them also possess qualities that make for successful harvesting by the combine. New and improved varieties are continually being developed by State and Federal agencies, and efforts are being made toward the standardization by communities of the best adapted varieties. Information regarding the best varieties for a particular locality is available at many of the State experiment stations.

One of the most important considerations in harvesting wheat with combines is to know just when to start the machine in the field. Since starting time is based mainly on the moisture content of the grain, it is well to understand the drying characteristics of wheat.

As wheat approaches maturity the kernel loses moisture rapidly, and after it has ripened (stopped growing) it dries out even more rapidly. Eight to ten days before wheat is ripe the kernels may contain as much as 50 percent moisture. At binder harvesttime, which

[2] Prepared in consultation with crop specialists of the Field Crops Research Branch, Agricultural Research Service.

is quite definitely known, the wheat may contain 30 percent or more moisture. Obviously, several days should elapse after binder harvesttime to allow the wheat to ripen, and several more days should elapse for drying before combining should be attempted. It usually takes 7 to 10 days of favorable drying weather after binder harvesttime before the moisture content is low enough (generally about 13 or 14 percent) for safe storage. To test for this degree of dryness, hold the center stem of the wheat head close to the base of the head with one hand and force the tip end of the head against the palm of the other hand and rotate vigorously. If about two-thirds of the heads sampled break, the moisture content is approximately right. If the wheat is damp the head is rarely broken during this simple hand test.

Ordinarily wheat that is in good condition is not difficult to combine. The standard setup on most of the so-called conventional-type combines is a cylinder speed of 1,000 revolutions per minute and the use of four rows of concave teeth. It is more difficult to knock the kernels from the heads of some varieties, Turkey, for example, and under more humid conditions of other varieties. In such cases more concave teeth must be used. It should be remembered, however, that the least number consistent with thorough threshing insures cleaner and more efficient threshing with less power.

Before adding more concaves, it is always a good plan to see that the concave teeth already in use are in good condition and that the cylinder speed does not drop appreciably below the standard rate when the combine is working under a load. Naturally the speed of the cylinder will be slightly higher when the engine is not under load. If there is lag in the grain being fed into the cylinder, placing the blank concave in the front position may overcome the difficulty.

If the wheat is being well threshed out of the head and if there is an excess of chaff and chopped straw, possiby fewer concaves may be used, they may be lowered, or the cylinder speed may be reduced. In reducing cylinder speed, remember that it changes the speed in the other working parts of the combine and that the power of the engine is reduced.

The kind, size, and number of sieves used vary somewhat with the make of combine, although the same fundamentals are applied in the separating operation. Where the adjustable sieve is used, its proper adjustment is frequently overlooked by operators to such an extent as to defeat the purpose for which it was intended. If the openings are too large, much material falls through the sieve before proper separation is possible; if they are too small, free passage of air is interrupted, with a consequent clogging of the sieve.

Wheat is the heaviest of the small grains and ordinarily will withstand or require more air blast in the separator and cleaner than other grains. The blinds of the separator shoe should be set to produce a blast strong enough to lift the chaff and light material and prevent it from falling through the sieves but not strong enough to blow the grain over.

Rye

The rye plant usually matures a few days earlier and grows considerably taller than wheat and consequently in the Eastern States has a greater tendency to lodge, especially in unfavorable weather.

On soils rich in nitrogen, rye has a natural tendency to lodge. Winter rye shatters more readily than wheat, and frequently it matures less uniformly. This is particularly true in years when the crop has not come through the winter well or when the spring is dry or otherwise unfavorable. Rye tillers, therefore, often are later in their development than the main stems. In this respect all the varieties of winter rye are somewhat similar.

Rye is generally easy to thresh, and the equipment and adjustments necessary in combining wheat are usually suitable for rye also. As rye straw is usually tall, the least possible number of concaves should be used in threshing, otherwise the straw will be badly broken up and make unnecessary work for the sieves. When damp, rye straw tends to wrap around moving parts. For this reason the cylinder speed should be about normal. If by a slight increase in cylinder speed fewer concaves will do the work properly, it is well to make this adjustment.

The drooping habit of the rye head necessitates cutting more straw than would be necessary were the heads erect. When heads droop away from the direction of travel the adjustment of the reel should be watched, otherwise many will fall in front of the platform after being cut and be lost.

Oats

The recent development of stiffer-strawed, rust-resistant, plump-kerneled varieties of oats with better standing ability has made this crop much more satisfactory for combine harvesting. However, some of these varieties have one disadvantage in that their straw remains green until after the grain is ripe.

Varieties now extensively grown include Clinton, Benton, Bonda, Bonham, Cherokee, Nemaha, Mohawk, and certain others derived from crosses on Bond oats. Since their green stems contain considerable moisture, combining should not begin until 10 days to 2 weeks have elapsed after the oats reach the binder-ripe stage. This period will be somewhat shorter in hot, dry seasons. Other varieties, such as Victory, Huron, Rainbow, Ajax, Beaver, Craig, and Branch, are less suited to combining than are those mentioned above because of taller straw, lighter grain, and more lodging or crinkling.

Oats are more subject to shattering and lodging after they are ripe than are wheat or barley. They are therefore often windrowed.

In favorable weather, ripe oats thresh readily with 1 or 2 rows of concave teeth and with a cylinder speed somewhat slower than that for wheat. Damp oats, however, require additional concaves and a somewhat higher cylinder speed.

Oats are much lighter in bushel weight than wheat and hence there is always more danger of blowing some varieties over the tailboard. Special attention should therefore be given to the adjustment of air used on the sieves. As a rule the shoe-fan blinds are closed down to one-fourth to one-half full capacity, depending on the condition of the crop. Also, to prevent the blowing out of too many oats, the tailboard usually is raised to the highest position.

In the Southern States several new disease-resistant fall-sown varieties are proving very satisfactory for combining. These short, stiff-strawed, plump-grained red oat varieties include Victorgrain 48–93,

Fulgrain, Fultex, and DeSoto. Other taller varieties such as Arlington, Atlantic, Southland, Forkedeer, Mustang, and Traveler usually lodge more quickly and the losses from combining are greater.

Barley

Ripe barley straw is usually brittle and crinkles down or breaks off readily or the heads break off easily. Ordinarily barley does not lodge badly. The Spartan (two-rowed-awn) variety is resistant to lodging. As a lodging precaution in the humid-spring region, barnyard manure should never be applied directly to the crop, as such a practice usually causes a rank growth and increases the danger of lodging. All barleys in humid climates shatter somewhat when ripe, the hooded and awnless sorts most easily. The types grown on the West Coast shatter much less than others. The types grown in the semiarid regions do not shatter readily.

In direct combining, barley should have a moisture content of not more than 13.5 percent when threshed, to insure safe storage. If the grain tank shows much green material the percentage of moisture should be much lower, unless the green material is got rid of before the barley is stored.

Barley is one of the easiest crops to thresh when dry, but when damp it is one of the most difficult. When thoroughly dry, it may be threshed with one row of concave teeth and with a cylinder speed somewhat less than normal. When damp, the grain is hard to knock from the heads, and as many as six rows of concave teeth may be necessary. Considerable light chaff is to be disposed of, including the beards and other material. Where the adjustable sieve is used, it should be opened more than necessary for wheat, since better wind action on the chaffer is thus obtained. Normally the same sieves used with oats are found satisfactory for combining barley.

Barley intended for malting purposes requires much more care in threshing than that grown for feed, and its value for this purpose can be greatly affected by improper threshing. The barley kernel is protected by hulls which surround the starchy interior. If these hulls are loosened or torn off the fungi whose growth is favored in the process of malting gain entrance and feed upon the kernel. Hence, broken or skinned kernels and those having broken-off tips are extremely objectionable. For this reason, close threshing should be avoided. Smooth-awned barley, such as Wisconsin Barbless, is easily injured in threshing and requires special care to avoid skinned kernels.

Buckwheat

Buckwheat continues to grow until checked by frost or drought, so there may be seeds and flowers on the same plants. Unless buckwheat is harvested before frost, considerable loss is likely to occur because of shattering. In direct combining, the judgment of the operator is necessary in determining at which stage the most mature seed can be saved. Under conditions extremely adverse to direct combining, such as heavy infestation with weeds, buckwheat may be windrowed, but when the crop is picked up and threshed there is usually considerable shattering loss. If windrowed, the crop should

be cut about the time the seed from the first lot of blossoms is fully mature, although the judgment of the operator as to a starting date is better than any set rule. Losses may be reduced by cutting in damp weather or when dew is on the plants.

When dry, buckwheat is easily threshed, the grain is easily cracked, and the straw is brittle. A comparatively slow cylinder speed (approximately 10 percent under normal) and few concave teeth are therefore requisite. Although generally one or two rows of concave teeth are used, under favorable conditions satisfactory threshing has been accomplished with the substitution of hardwood boards for concave teeth. This reduces the cracking hazard and at the same time aids in separating and cleaning, since the straw is less broken up. Good results with buckwheat are obtained by using the same method and equipment as with wheat.

Emmer and Spelt

Emmer and spelt are grown to a limited extent in this country. They differ from other wheats in that most of the kernels are not removed from the chaff in threshing. The heads of both grains are easily broken at maturity. In very dry regions where the grain becomes dead ripe, some shattering loss is probably unavoidable, especially if there is wind. Combining should start as soon as the grain has dried out sufficiently for safe storage, which is usually at a 13- to 14-percent moisture content.

No special equipment or adjustment of the combine is necessary in harvesting emmer and spelt, which are quite easily threshed under normal conditions. The machine setting and adjustments are about the same as for oats and barley, except that possibly the cylinder speed should be slower. Care should be exercised, however, to prevent knocking too many kernels from the chaff. The number and setting of the concaves should be sufficient to break up the head of the plant completely without dehulling an appreciable number of kernels. Concave adjustment should be made to correspond to changes in the moisture content.

Flax

All standard varieties of flax have straw that is strong enough to stand up well. The flax plant matures at a height of 20 to 30 inches, depending upon variety and season, and the seed of the more common varieties ripens rather uniformly. Lodging sometimes occurs from attacks of rust, which weaken the stems and cause them to fall over. Most of the varieties now widely grown in the Northern States, except Bison, are at least moderately resistant to rust. Shattering does not occur to any appreciable extent unless there are heavy winds when the crop is ripe and dry. Under normal conditions the open bolls will stand 2 to 3 weeks with but little hazard from shattering. More loss of flax in delayed harvest is likely to result from insects cutting off the bolls than from lodging or shattering.

As the flax plant approaches maturity a few of the early bolls near the base of the panicle begin to crack open, in a few days the majority of the bolls open, and the rest shortly thereafter. Then the whole

plant turns brown, the leaves shrivel, and the stems become dry. This is common to practically all varieties ordinarily grown for seed or fiber in the United States. The bolls of the Argentine strains, however, remain tightly closed when ripe. With the common varieties the ripe bolls are highly hygroscopic (water absorptive), the bolls opening as they dry out but closing tightly again when wet by dew or rain. This characteristic may be used as an indication of the proper condition of flax for combining, as at the open stage its moisture content is considerably under 11 percent, which is considered safe for storage.

Some varieties of flax, the Indian and Punjab (Cereal Investigation No. 20), for example, grown in California, are particularly difficult to thresh, the bolls being tightly closed when the seed is ripe. This and other varieties are frequently combined by the windrow method in California, and the windrowed swath is sometimes left as long as 3 to 4 weeks before the flax is in proper condition to thresh.

Flax plants when cut have a tendency to bunch or cling together, especially along the front side of the platform. To avoid this, be sure that the cutting mechanism is in as good condition as possible. The reel should be set directly over the sickle bar and as low as is possible without danger of serious contact. Strips of belting or other material fastened along the outer edges of the reel slats will facilitate brushing the cut plants well back on the platform and at the same time minimize the danger of broken slats. A rather high cylinder speed will also prevent a tendency to wrap with tow, which is bothersome and delays field operations.

A cylinder speed 10 to 20 percent above normal is used in combining flax, the speed of the separating mechanism being maintained at normal by special sprockets. Four to six rows of concave teeth set high are used, depending on difficulty of threshing. If the straw happens to be dry, just as few concave teeth as will properly do the job should be used, because at a high cylinder speed a greater quantity of finely cut material will go over the sieves.

Since the flaxseeds are light, the direction and volume of the wind blast are important, and special sprockets, if provided, should be used for cutting down the volume of the blast. The wind board in the shoe should be adjusted so that the blast strikes the sieve as far forward as possible without resulting in the chaff clogging the rear part. If this latter condition is apparent, direct the blast more toward the middle of the sieve until it reaches a point at which the rear of the screen will stay clean. If adjustable sieves are used they should be set somewhat closer than for wheat. The small round-hole sieve is frequently used as a secondary sieve.

Direct combining is advised, provided the field is practically free of weeds and the flax has ripened uniformly. This method may also be followed if harvest is delayed until a few days after frost. At such a time weeds dry rapidly, and usually flax will stand for a considerable time without loss from shattering. Where fields are weedy and also where damp, cool weather delays ripening, the windrow method should be used. To avoid damage in the windrow in adverse stubble conditions, such as stubble containing Russian-thistle, flax should be picked up and threshed as soon as dry.

FIGURE 13.—Harvesting flax with combine fitted with a flax-roll attachment.

As noted under attachments, page 13, flax-roll attachments are available for most combines to adapt them for flax harvesting. Figure 13 shows a combine equipped with such an attachment at work in a flaxfield.

Soybeans

All soybean plants reach a definite size, according to variety and environment, and then mature and die. The leaves begin to turn yellow and drop when the plant approaches maturity and in most varieties they have fallen before all the pods are fully mature. The time of harvesting will vary somewhat with weather conditions. In a hot, dry fall, greater care should be taken with varieties that tend to shatter.

Soybean maturity puts the harvest at a time likely to be unfavorable on account of bad weather and weed growth. Hence, once the beans are ready, the harvest should go forward, if possible, without interruption. Not only is a badly lodged crop in a weedy field difficult to harvest but any beans on the ground will soon become damaged.

Present improved soybean varieties, such as Monroe, Blackhawk, Hawkeye, Adams, Lincoln, Wabash, Perry, Dorman, Ogden, and Roanoke, are better adapted to combining and less susceptible to shattering than previous varieties.

Of the improved varieties Hawkeye and Blackhawk are extremely resistant to lodging. The others are at least moderately resistant. At present Hawkeye is grown on 25 percent of the soybean acreage of the United States and the acreage of Blackhawk is increasing rapidly. The Wilson, Virginia, Laredo, Lincoln, and Otootan varieties frequently lodge badly in fertile soils, and under such conditions they are difficult to harvest. Older varieties such as Richland bore pods down to the ground level and sickle bar losses were unavoid-

able. Varieties such as Hawkeye seldom bear pods lower than 4 inches from the ground.

To harvest soybeans with a combine calls for special or extra equipment, which is obtainable from the several manufacturers. This includes pulleys and a belt for reducing cylinder speed (many makes have adjustable cylinder speed) and sprockets for maintaining normal speed for the rest of the separator. In some cases special sieves are recommended, although soybeans can be harvested with the regular sieve equipment used for wheat. Under some conditions pea and bean concaves are used. These permit greater clearance between the cylinder and the concave teeth and reduce splits to a minimum (fig. 14).

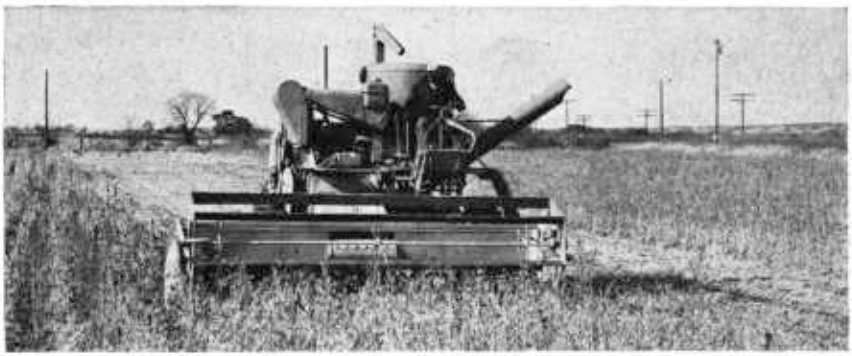

FIGURE 14.—A combine harvesting soybeans.

Mature, dry soybeans are easily knocked from the pods, but, because of nonuniformity of ripening, some threshing action is needed to get many of them. As the mature beans tend to crack or split as a result of the action of the cylinder, the chief problem is to harvest as much of the crop as possible with a minimum of splits. No definite rules for this can be laid down, but a cylinder speed about 50 percent of normal is usually satisfactory. The actual speed should be the maximum at which only a reasonable number of beans will be split, as this will insure a minimum number left in the pods. One to three rows of concave teeth are normally used, although none or more may be needed under extreme conditions.

More air blast will be necessary than for wheat, and better cleaning may result from the use of a weed screen with openings larger than those used for small grains. Because of the prevalence of down plants at harvesttime, the cutting may be expedited by the use of special guards or pickup fingers. These are bolted to the cutter bar about a foot apart and raise the down vines so they may be readily cut and delivered to the platform. Low-cutting bars also are available for some machines.

Peas

Under normal conditions peas mature uniformly and shell out readily. Thus they cannot be left standing long after maturity without heavy loss by shelling. Direct combining should not be attempted until the pods are sufficiently dry to be threshed with few or no concave teeth and with the cylinder speed reduced about 50 percent to minimize cracking.

In windrowing the cutting should begin when the peas have become firm. If it is delayed until both vines and pods are dry, the loss from shattering is sure to be large. If rain falls on the peas during the curing period, they should be turned over as soon as those in the top layer are dry. Otherwise, the peas underneath will swell and burst the pods, so that when they become dry a large proportion will shell out and be left on the ground.

The threshing and cleaning of peas is similar in methods and machine setup to that of soybeans. In the Northwest the combine was first used as a stationary thresher; then, as windrow equipment developed, windrowing was largely used in harvesting the crop. The losses of peas because of the shattering due to repeated handling in both stationary threshing and windrowing were heavy.

The direct combining of peas calls for special equipment and adjustments in the threshing, separating, and cleaning units. A slow cylinder speed is necessary, with a minimum of concave teeth and with the rest of the separator running at normal speed. A slow-speed (275 r. p. m.) cylinder drive is included in the special equipment for some combines. (See Soybeans, p. 29.)

Dry Beans

Beans are always cut and then allowed to dry, regardless of the method of threshing. Where stationary threshers are used, the beans are often bunched and not windrowed. Where the combine is used, special attention should be given to the number of rows brought together for the windrow for combine pickup. The bulkiness of the crop, which, of course, will vary from year to year, and the size of the combine used in threshing will determine the size of the windrow. A fairly safe rule to follow is to limit the windrow to the number of plants that could be grown on ground the same width as the cutter bar. Any doubt as to size of windrow should be resolved in favor of the smaller size because of the difficulties in handling excessive quantities of material through the machine.

Beans are normally cut when the pods have turned yellow and before they have dried out. Usually the vines are thoroughly dry within 2 to 3 days after cutting and are then ready to be picked up and threshed by the combine. If rain falls while the beans are in the windrow they should be turned, preferably with a side-delivery rake. Pods should not be allowed to lie long on wet ground, as beans readily absorb moisture and may become discolored.

Most varieties of beans are normally not difficult to thresh, but when dry they split easily. The problem then is primarily one of cylinder speed and concave adjustment. Usually, beans can be threshed with a cylinder running at 50 to 70 percent under normal. At this low speed it is often necessary to use all the concaves or concave teeth to do satisfactory work. As with soybeans, care should be exercised in providing sufficient lateral clearance between cylinder teeth and concave teeth of spike-tooth cylinders to minimize cracking, and enough clearance between cylinder bar and concaves of rasp-bar and angle-bar types.

The adjustment made for starting the machine in the morning, if the bean pods are damp, will doubtless need to be changed later in the day when the pods have dried out. In regulating for close threshing

no attempt should be made to save the green, immature beans, for in so doing an adjustment may be necessary that would result in considerable splitting of those that are dry and mature. No special sieves are necessary for combining beans. The same ones used in small-grain threshing are satisfactory.

Rice

Climatic conditions, trade preferences, and milling standards restrict to a considerable degree the varieties of rice grown in this country. From the harvesting standpoint, the varieties grown may or may not be those most suitable. All desirable characters are seldom embodied in any one variety, on account of the conditions under which rice is grown and the variation in some of the plant characteristics. Stiffness of straw, uniformity of ripening, and resistance to lodging, shattering, and disease are important factors in a successful harvest. In California early maturity and high-yielding capacity are of considerable importance. Some early varieties are not grown, because they produce poor field or milling yields of head rice.

Because of the frequent rains and unfavorable weather conditions at the rice harvest, the resistance of the crop to lodging, shattering, and disease is obviously important. Many of these hazards may be averted in the South by growing early-maturing varieties, but yield and other important factors also must be considered. The use of pure seed will likewise lessen the harvest problems arising from unevenness in heading and ripening.

One characteristic of the rice kernel is its tendency to become damaged by checking when subjected to changes in moisture and by too rapid drying in hot weather. Check damage is one of the factors contributing to poor yields of head rice in milling. Because of this and the possibility of lodging and shattering, the crop will not stand long after maturity without considerable loss in yield and milling quality. If the crop is allowed to stand in the field until dry enough for safe storage, the kernels will check and a low yield of head rice will result.

Practically all of the rice in California and much of that in the Southern States is now harvested by the combine-drier method. To get rice having a minimum number of checked kernels with the combine-drier method, it is best to harvest the crop when the grain has dried to 18 to 25 percent moisture and to reduce the moisture gradually to about 14 percent by artificial drying.

When combining rice, cutting should begin as soon as the kernels in the lower part of the head are in the hard-dough stage. This stage of maturity is indicated by the position of the heads, which are well turned down, and by a moisture content of 21 to 28 percent. If the rice is cut earlier the quality will be greatly affected by a large percentage of immature chalky kernels. If the rice is cut later there may be a loss of grain from shattering and a reduction in the yield of head rice due to checking.

In direct combining, care should be exercised not to crowd the feed. Because of the heaviness of rice straw the ground speed of the machine should be slow enough to avoid clogging. The rice kernel is very susceptible to cracking, and for this reason the cylinder should be run

at a slightly reduced speed. If the crop is damp and does not thresh out well, try increasing the speed slightly, being sure to watch for cracked kernels. Allowing a small percentage of kernels to crack may be necessary to threshing out a maximum yield.

As rice is generally easy to thresh, the number of concaves used should be carefully watched to avoid overloading the sieves with a large mass of chopped material. In humid sections grain dries slowly after night dews, so the condition of the grain rather than any set time should govern the starting of the machine each day. Furthermore, as the grain dries out during the day the setting of the machine will probably need to be changed for best work.

Special self-propelled rice combines used in California are equipped with crawler tracks which enable the machine to cross wet spots and small ditches and low levees. Self-propelled combines used in the ricefields of the South are usually equipped with large tires with mud lugs.

Grain Sorghums

Nearly all of the commercial grain sorghum crop is now harvested with combines.

Plant characteristics of the grain sorghums affect combining practices. Considerable variation exists in the stalk, head, and seed of the plants. The heads do not ripen uniformly, the grain at the top of the heads ripening about a week earlier than that at the bottom. The heights, lodging, juiciness, and tillering habits of the stalk are also important.

Plants under 40 inches in height are considered satisfactory for combining; taller varieties are more likely to lodge and are difficult to cut. Some of the dwarf varieties, including Martin, Plainsman, Westland, Midland, Caprock, Redbine 60, Combine Kafir 44–14, Redlan, Norghum, Reliance, Bonita, and Double Dwarf 38 milo, usually range from 24 to 42 inches in height and are especially well adapted to combining. Lodging is usually associated with tall slender stalks and large heads, but there are varietal differences in strength of stalk. Lodging occurs after the stalk has dried out following maturity, frost, or extreme drought or when attacked by stalk rots. Very thick stands have a greater tendency to lodge than thin stands.

Tillering habits of the stalk are important because tillering results in variation in height and in uneven ripening, leaving part of the grain immature at harvesttime. If harvest is delayed until the tiller heads are mature, the ripe main heads are subjected to weathering. Of the varieties listed above, Bonita tillers are very susceptible to lodging, those of Martin slightly, and tillers of the other varieties moderately.

Erect heads, as are found on the combine types mentioned, give less trouble in harvesting. Double Dwarf 38 milo normally produces many recurved heads, but when planted thick on rich irrigated land in California and Arizona nearly all of the heads are erect. The head of a desirable variety for combine harvesting should extend above the leaves to permit heading without taking many leaves into the machine. The taller stalks of such varieties increase the tendency to lodge, however, and after frost or maturity the upper leaves are so dry that they scarcely interfere with threshing.

Except where drying facilities are available combining should not be attempted until the grain has dried out enough to be stored safely.

A moisture content of 13 to 14 percent is usually considered safe. In the absence of moisture-testing apparatus the moisture content can with experience be determined approximately from the "feel" of the grain, by crushing it between the teeth, or by denting it with the thumbnail. Considerable grain sorghum is now being dried artificially, especially in southern Texas.

Because of the poor drying conditions usually occurring at the time of harvest, several months may elapse in extreme cases between maturity and the earliest possible harvest dates. These and less extended delays cause much of the crop to be harvested before it can be safely stored and results in much of it heating and going out of condition.

Ideal harvest conditions are provided after a severe freeze, especially following a maturing period of dry weather. Another few days of drying weather will considerably reduce excess moisture so that the grain can be stored without danger of heating.

Martin, Plainsman, Westland, and Midland are adapted to western Kansas, Oklahoma, and Texas, but on account of susceptibility to chinch bug injury they are not a safe crop east of the 25-inch average annual precipitation line in those States. The resistant varieties such as Combine Kafir 44–14, Redlan, and Combine Kafir 60 are satisfactory.

The combine can be used either directly or as a stationary thresher to harvest grain sorghum, depending on the conditions under which the crop is grown. When used as a stationary thresher, the combine is moved up to each rick of heads. For threshing bundles of grain sorghum an upright sickle bar is rigged upon the header and the regular pitman drive used. With such an arrangement, shocked and cured bundles of grain sorghum are laid over the sickle bar by hand so that the heads will be cut off and fed to the combine. The remaining part of the bundle is saved for feed.

In direct combining it is important that the header platform be raised to a suitable height, depending on the height of the crop, the reel slats widened, and screens placed at the back and ends of the platform to cut down harvesting losses.

The grain, when dry, is easily knocked out of the heads, and the chief threshing problem is to avoid cracking it by excessive cylinder speed. Ordinarily, a speed 20 to 25 percent under normal is found to result in little if any cracking. In attaining this speed it may be necessary to change sprockets so that the rest of the mechanism will run at normal speed. It is seldom necessary to use all the concaves. The number to be used depends entirely on the condition of the grain. Under good threshing conditions the crop can be threshed by using two rows of concave teeth.

The stalks, leaves, and heads of grain sorghums usually contain considerable moisture when harvested. This wet material, or pomace, is frequently chopped up so that it falls through the straw racks and is too heavy to be blown out with the chaff. Consequently much of the pomace is repeatedly returned to the cylinder by the tailings elevator until it is ground fine enough to pass out with the grain. Its presence in the grain increases the danger of heating. To avoid this difficulty a piece of sheet metal should be placed over the space between the chaffer and the tailboard to prevent the pomace from falling into the tailing chute.

Clovers

Clovers and similar small-seeded crops are as a rule more successfully harvested with combines by the windrow and swathing methods. Unfortunately seeds of most clovers when mature shatter readily, so that extreme care should be exercised in handling the crop regardless of the method used. Much can be done, however, to facilitate combine harvesting by proper planting and management of the clover-seed crop. Those varieties and kinds having habits of medium plant growth, of uniform seed maturity, and of holding their seed at maturity can be combined with less loss.

Some of the clovers, particularly those that develop new growth as the seed-bearing stems are maturing, are best handled by the windrow or swathing methods. Regardless of the variety or kind of clover, cutting at night or early in the morning, when the plants are wet or damp with dew, will cause less seed shattering than that done when the plants are dry.

Harvesting clovers and small-seed crops with combines presents many problems. Large bulky plants frequently require the services of an extra man to guide or push the plants onto the platform and up into the feeder house of the machine. Also, on account of the small size and light weight of the seed, the problem of separation is especially difficult, and at times the operator must choose between getting a poor job of cleaning or a considerable loss of seed. As a rule, however, as much of the seed as possible should be saved; it can be recleaned later.

To prevent excessive heating when much damp, green material appears in the grain tank, it may be necessary to spread the seed in thin layers to dry on the barn or granary floor for recleaning before storage. Under many conditions the artificial drying of clover seed is essential to obtain high-quality seed. This is particularly true during periods of damp rainy weather when the seed crop is being harvested.

In combining from the windrow the stems will be more broken in passing through the cylinder, giving the sieves greater duty, but the trash and foreign material in the grain tank will probably be comparatively dry, so that the seed can be stored with less danger of heating from this source than if stored with green material.

In threshing clovers, close concave setting, a cylinder speed somewhat above normal, and the use of special corrugated concave teeth are frequently necessary to rub the seed out of the head. This, of course, adds to the difficulty of separation on account of the finely chopped condition of the material passing over the sieves. This material should be disposed of quickly. In doing this a few seeds may be blown out the rear end of the combine, but this is better than overloading the chaffer. Occasional observations for damage should be made of the seed as it is discharged from the grain spout. If much damage is apparent the concave setting should be increased slightly or the cylinder speed should be decreased slightly.

The air blast is an important consideration in combining clover. Fan blinds are usually closed as far as possible to prevent blowing the seed out the rear end of the machine. If they are available, use special sprockets for cutting down the speed of both the shoe fan and the recleaner fan instead of shutting down the fan blinds. The loss

of seed by air blast may be corrected to a certain extent by so directing the wind that it strikes the sieve as far forward as is possible without unduly impeding its proper functioning.

Because of the small size of the seed the special sieves recommended by the manufacturer should be used. If the adjustable sieve is used, its proper setting is important. When a recleaner is a part of the combine, the seed should feed evenly over the sieve and the sieve should be covered with material over the greater part of its surface. Allowing the material to fall through the sieve in a pile defeats the purpose of the sieve.

Since in many sections the mower and rake are used in making the windrow, the determination of the size of windrow is important. It is much better to have it too small than too large. The size will, of course, depend upon the bulkiness of the crop and the width of the cutter bar of the combine. A fairly safe rule to follow is to limit the windrow to the quantity grown in a strip as wide as the cutter bar of the combine. Hence, for a 10-foot combine a windrow bunched from two swaths of a 5-foot mower is about right.

The crop may be tough and difficult to thresh when there is bad weather after the windrow is laid. If this happens, the operator can only slow down the ground speed of the combine.

While with all crops the combine should be watched for leaks of grain, this is especially necessary in the case of small seed. Clover seed can pass through a very narrow crack or space, and an opening large enough for a kernel of wheat to pass through would be adequate for a small stream of clover seed.

Studies by the University of California Agricultural Experiment Station at Davis indicate that spray-curing and direct combining of small-seeded legumes are feasible under favorable conditions. As a result direct combining of legume seed crops in California has considerably increased in the last several years.

The first step in treating such crops is to spray it with a contact weed killer such as the dinitro general type in diesel oil. This kills the vegetation above ground and causes it to dry rapidly. Direct combining may then be started 1 to 5 days after spraying even though the entire plant is not dry.

Various crop characteristics influence the use of sprays. The crops should be open and erect to permit adequate penetration of the spray. If thick or matted, two applications may be necessary, the first for killing outside growth and the second, applied a few days later, for contacting the lower protected foliage.

Timing is also important. Enough time must be allowed to permit the crop to dry out sufficiently after spraying but not too long to cause shattering in some crops or regrowth in others.

As the seed in a spray-cured crop generally has a relatively high moisture content the seed should be dried soon after harvesting. If the straw is to be fed to livestock it should be aired out some 10 to 15 days.

Because of the high moisture content of the seed a 500-foot per minute increased cylinder speed can be used.

The studies in California show that the use of flax-roll attachments would be advantageous in harvesting of these crops. These permit lower cylinder speeds and minimize seed damage and loss.

In cleanup operations after harvesting, particularly in the case of Ladino clover, vacuum machines are often used for picking up the shattered seed. These are generally custom made and in California most Ladino growers contract with specialists to harvest their seed.

SWEETCLOVER

Sweetclover is difficult to harvest for seed even under favorable conditions. This is particularly true of the biennial white, which grows to a height of 5 to 8 feet and is troublesome in combining because of its bulk and easily shattered seed. In producing a seed crop the growth is frequently either cut for hay, pastured down until June, or clipped. Any of these treatments causes the plants to branch more freely and the seeds to mature more uniformly, which make harvesting easier. When the early growth is pastured, clipping is advisable to develop uniform maturing plants.

A combine works best when the crop is dry, and at that time there is considerable loss from shattering. If combining is done at a time suitable for saving the most seed, a considerable quantity of leaves, broken stems, and immature seed will need to be disposed of in the separation. The choice between direct combining, windrowing, and swathing will frequently depend on crop and weather conditions.

In direct combining of sweetclover the reel usually needs to be slowed down and adjusted to meet more nearly the requirements of the bulky plants. The speed of the pickup tine-bar assembly should be no greater than the ground speed.

RED CLOVER

A larger and more easily handled seed crop of red clover can generally be obtained by cutting, pasturing, or clipping the first crop and harvesting a later crop for seed. As a rule these later crops, correctly handled, are more uniform in height and maturity, produce a greater yield, and are better adapted for combine harvesting than the earlier ones.

Red clover may be combined direct or preferably, except during dry seasons, harvested by the windrow and swathing methods. Harvesting by combine should begin when the heads of the clover are brown. There will be some loss from heads of plants breaking off and seed shattering. The best time to cut the clover for windrow harvesting is when the heads have turned brown, the flower stalks are deep yellow, and the seeds have begun to show a distinct violet color. If cutting is delayed, loss of seed from breaking off of heads is certain to be heavy. Windrowing and swathing can be done earlier if the stems are heavy and full of sap than if they are short and dry.

CRIMSON CLOVER

Mature seed of crimson clover shatters more readily than that of red clover. It is best combined when the heads of the plants are brown, which is indicative of seed maturity. At this stage the seeds are easily rubbed out of the head in the palm of the hand. If there is considerable acreage to harvest and the crop is uniformly ripe there will doubtless be some field shattering before the completion of the harvest, especially in the event of rain or wind. In that case it may be well to start harvesting a little early.

In windrowing and swathing crimson clover the cutting should begin about a week or 10 days after the last blossoms have faded and when the last-maturing seeds in the top of the head have reached the soft-dough stage. To minimize seed shattering the plants should be somewhat damp, as with dew, when windrowed.

ALSIKE CLOVER

When the growth of alsike clover promises to be rank the field may be pastured until about June 1. This will cause many additional shoots to start, each bearing flower heads and thus increasing the yield of seed. Owing to the irregular flowering habit of this clover there will be overripe heads as well as buds on the same plant, and in direct combining a loss will result both from the presence of immature seeds and from the shattering of those that are mature. For this reason the windrow and swathing methods are usually preferable. The operator's judgment should determine the best time for harvesting to get the most seed.

In windrowing, the crop is usually cut when about three-fourths of the heads are ripe.

Alfalfa

On account of the uneven ripening and shattering of the seed, alfalfa is seldom combined direct. One harvesting method is to cut the crop with a mower equipped with a buncher or windrow attachment and to combine from the windrow (fig. 15). The self-rake reaper is sometimes used. The cutting time is important—if too early, there

FIGURE 15.—Combining alfalfa from the windrow.

will be many immature seeds; if too late, much of the seed will be lost in shattering. The operator's judgment must determine just when to cut the crop in order to save a maximum quantity of seed. This is usually when two-thirds to three-fourths of the seed pods have turned brown. As indicated on p. 36 in reference to clovers, spray-curing to aid in harvesting is also applicable to alfalfa.

For a satisfactory job in threshing alfalfa special or extra machine equipment is frequently necessary. This may include, according to the make of combine, special concaves with corrugated teeth, special sieves, sprockets for reducing fan speed and for increasing the cylinder speed while maintaining a normal speed for the separator. Close concave setting and corrugated concave teeth are usually needed to aid in the threshing. A cylinder speed somewhat above normal is generally required, with separator speed maintained at normal. (For additional information, see Clovers, p. 35.)

Lespedeza

The method to be used in harvesting annual lespedeza seed will depend on the condition of the crop and the variety. If the crop is tall enough it can be combined direct. The seed, however, must be dry enough to be threshed effectively. When the plants are short, a mower equipped with a windrower is sometimes used. If the windrow method is used, the crop is generally cut when the seeds are mature and while the plants are damp or wet, as with dew. If a large combine is used for picking up, 2 or 3 windrows can be raked together when damp, or if a wide pickup is available, several small windrows can be picked up at the same time.

Seed of the varieties of striate lespedeza, such as Kobe and Common, shatter readily at maturity. Korean, Rowan, and Climax shatter much less, but seed losses due to shattering can be severe if harvesting is delayed too long after maturity. Experienced seed producers examine their fields at frequent intervals and begin harvesting or combining operations as soon as the seeds are mature.

Maximum yields of seed of sericea lespedeza are usually secured when the full season's growth is allowed to make seed. However, producers have found that the excessive, coarse full-season growth is difficult to combine. The usual practice is to take off an early cutting for hay and allow the second growth to make a seed crop.

Sericea will shatter and much of the seed crop can be lost if harvesting is done after the seeds are mature. Seed harvesting should begin as soon as most of the pods are brown. Most of the sericea is combined directly. The instructions of the manufacturer should be followed in setting the combine for harvesting sericea seed with minor adjustments being made as needed.

Since much of the lespedeza seed is harvested while the plants and leaves are still green, special care is necessary in handling. The freshly combined seed will usually contain bits of green leaves and other trash having a high percentage of moisture. The removal of this green trash by cleaning immediately after combining reduces the chances of heating, but the seed must also be dry before being stored. In many localities there are seed cleaners and driers for taking the seed directly from the combine. Where such facilities are not available the seed should be spread out and stirred frequently to prevent heating.

Timothy

Timothy has been combined successfully both directly and by the windrow method. Direct combining is recommended if the crop is uniformly ripe and free of weeds. Timothy will not stand long after maturity without shattering its seed; and, if there is considerable acreage to cut, it may be advantageous to windrow at least a part of it to guard against shattering. From the standpoint of safe storage, windrowing is preferable to direct combining as there will be no heating from green material or immature seed.

Combining is ordinarily done with a normal cylinder speed and four rows of plain concave teeth. In threshing timothy it is not necessary that the seed be hulled. As a matter of fact, the hulls often serve to protect the seed from the entrance of certain plant diseases. The germination of timothy seed having hulls is usually higher, especially after the seed has been stored for several years. When the hulls are to be retained, a slower cylinder speed may be used, with the concaves lowered.

As timothy seed is small and light, it is necessary to keep the wind blast down; otherwise, much seed will be blown away and lost. Sprockets for reducing the fan speed should be used, and the wind board should be adjusted in such position that it will direct the blast to the front end of the shoe sieve.

Millet

Combines are not suitable for harvesting all classes of millets. The foxtail millets can be combine harvested with satisfactory results if they are seeded early enough to insure maturity and to overcome the difficulties of late harvest. Pearl millet is generally harvested with a binder, although a header can also be used with the lopped heads being threshed in a stationary combine. The crop should be thoroughly dried before threshing. Attempts are being made to develop low-growing strains of pearl millet that may lend themselves to combine harvesting.

Millet may be combined either direct or from the windrow, depending on local conditions. It should be windrowed just as soon as the seed in the head can be rubbed out in the hand. The proso type of millet grown for grain (known as Hershey, Early Fortune, Manitoba, or hog millet) does not ripen uniformly in the head, it shatters easily, and the stems and leaves remain green after the seed ripens; consequently proso is rarely combined direct. When the seed is dry, it is easily threshed with a slow cylinder speed, the rest of the machine running at normal speed. When the crop is damp, it is necessary, of course, to speed up the cylinder. Ordinarily close concave setting is not necessary.

Crotalaria

Crotalaria seed is harvested with combines, mowers, and by hand picking. Species that ripen seed fairly uniformly are best suited for handling with machinery. Species that ripen seed unevenly or over a long period must be harvested by hand if a maximum quantity of seed is to be obtained.

Crotalaria spectabilis and *C. lanceolata* are perhaps the easiest species to handle for seed. *C. anagyroides* is the most difficult. It is very large and coarse growing and ripens its seed unevenly. Late

planting will reduce the size of plants to some extent and still permit seed setting and facilitate harvesting. In Texas, *C. juncea* planted in July made about half as much growth as that planned early and matured seed that could be easily harvested with a combine.

Crotalaria is not difficult to thresh when dry but will give some trouble when harvested before fully mature. After the seed is threshed it must be artificially dried or spread thinly on shed floors where it can dry naturally. If the seed is allowed to heat, it will reduce germination. When hand-harvested, the seed pods are gathered and spread to dry before hulling or threshing. Special crotalaria threshers have been built, but ordinary threshers, if properly adjusted, will hull the seed satisfactorily. By the use of screens and ordinary fanning mills the seed can be cleaned without difficulty.

Lupines

Harvesting lupine seed should be begun before the plants are quite mature, and when a mower is used the crop should be cut while dew is on the plants. In yellow lupine the seed shatters readily when allowed to mature, and in blue lupine moderate shattering occurs. White lupine retains its seed well. A combine can be used if the crop is mature. In threshing, use a combine or a thresher adapted to peas or beans. Mature seed flails easily, making it possible for growers of small acreages to save seed for home use without special threshing equipment. Most species produce seed abundantly. In Florida 1,200 pounds per acre frequently has been obtained from blue lupines.

Lupine seed ripens somewhat unevenly and contains a high percentage of moisture until thoroughly ripe. To get the most seed it is necessary to cut the crop with a mower or to harvest with a combine when the seed still contains considerable moisture. The average moisture content of the seed as commonly handled is so high that special care must be taken to dry the seed thoroughly after harvesting.

Large green seed when harvested may contain as much as 30 percent moisture. For safe storage, the moisture after harvest should be reduced as rapidly as possible to 12 percent. To reduce danger of damage by spontaneous heating, the newly threshed seed should be cleaned of trash and large green seed as it comes from the combines. The clean seed may then be dried down to 12 percent moisture either artificially or it can be spread out and stirred frequently to prevent heating until dry enough for safe storage. One probably must learn by experience the proper stage of ripeness at which to harvest; however, the riper the seed is, the less danger there is from deterioration, but the probability of loss from shattering is greater. It has been determined experimentally that lupine seed loses moisture rapidly and seed that contains as much as 30 percent moisture one day may have little more than half as much the following day if it is exposed to free air circulation. Without good air circulation and drying conditions, seed containing 15 percent moisture or more will deteriorate rapidly at ordinary summer temperatures.

Safflower

Safflower is well adapted to direct combining and may be harvested as soon as the late heads are dry and thresh easily by hand. This stage may come when a few green leaves are still present on the plants. Some shattering may occur during harvest if the crop is left standing

after it matures. The amount of seed lost is influenced by the variety grown and the dryness of the plants at the time of harvest.

No major modification of the combine is required for harvesting safflower but it is necessary to use a slower cylinder speed than is used for barley or wheat. Cylinder speeds of 400 to 800 r. p. m. usually give satisfactory threshing without cracking the seed. With spike-tooth cylinders, concave teeth should be reduced to 1 or 2 rows or removed. It may also be necessary to lower the concave to the position illustrated in figure 7, *B*. Combine settings for rice have given satisfactory results with safflower in California.

Combines with bar-type cylinders should be adjusted to ½- to ⅛-inch clearance between concaves and cylinder, depending on the dryness of the plants. Shaker speeds slightly faster than commonly used for grain and wind and sieve adjustments used for barley have given good results with safflower.

Most of the seed loss from the reel can be eliminated by attaching a 4- to 6-inch strip of flexible belting to the reel slats and raising the reel so that only the top of the belting hits the plants. The reel slats may catch the heads and cause shattering but this difficulty can be eliminated by filling in the space between the reel arms with canvas or fine-mesh, heavy-gage wire screen.

TROUBLE CHART

A. Loss of grain by reel and platform.
   1. Reel not set to throw grain well back on canvas.
   2. Reel set too high to pick up lodged grain.
   3. Reel slats too narrow.
   4. Platform backstop too low.
   5. Outer end of platform not screened.

B. Cracked grain.
   1. Cylinder speed too high.
   2. Concaves set too high or too many concave teeth.
   3. Concave or cylinder teeth bent or out of alinement.
   4. Concave not parallel with cylinder.
   5. Cylinder and concave clearance too small.
   6. Threshed grain returned to cylinder with tailings.
   7. End play in cylinder shaft.

C. Grain loss in straw.
   1. Unthreshed heads.
      a. Grain too damp.
      b. Cylinder speed too slow.
      c. Concaves set too low or not enough concave teeth.
      d. Concave or cylinder teeth bent or out of alinement.
   2. Threshed grain.
      a. Too much wind.

C. Grain loss in straw—Continued
   2. Threshed grain—Continued
      b. Wind blast not properly directed.
      c. Cylinder and separating units running too fast.
      d. Straw agitators running too slow.
      e. Overloaded sieves or straw racks.
      f. Proper sieves not used.
      g. Sieves not properly adjusted.
      h. Straw chopped up badly.
         (1) Too many concave teeth.
         (2) Concave set too high.

D. Poor cleaning.
   1. Sieve openings too large.
   2. Elevators clog.
   3. Sieves overloaded.
      a. Feed too heavy—too much straw.
      b. Speed too slow.
      c. Straw chopped up too fine.
   4. Deflectors out of adjustment.
   5. Not enough wind.
   6. Weeds.

E. Cylinder clogs.
   1. Straw green or damp.
   2. Cylinder speed too slow.
   3. Feed too heavy—too much straw.

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